MARINE COATING PERFORMANCE
A SIX YEAR REPORT

October 1985

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FOREWORD

This project was performed under the National Shipbuilding Research Program. The project, as a part of this program, is a cooperative cost shared effort between the Maritime Administration and Avondale Shipyards, Inc. The development work was accomplished by Associated Coatings Consultants under subcontract to Avondale Shipyards, Inc. The overall objective of the program is improved productivity, and therefore, reduced shipbuilding costs.

The studies have been undertaken with this goal in mind, and have followed closely the project outline approved by the Society Of Naval Architects and Marine Engineers' (SNAME) Ship Production Committee.

Mr. Benjamin S. Fultz of Associated Coatings Consultants served as principal investigator. Mr. John Peart of Avondale Shipyards is the R&D Program Manager responsible for technical direction and publication of the final report. Program definition and guidance was provided by the members of the 023-1 Surface Preparation and Coatings Committee of SNAME.

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Napko, Houston, Texas
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Porter Coating. Louisville, Kentucky
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Sigma, New Orleans, Louisiana

Executive Summary

The objective of this project was to continue a series of exterior test performance studies which began in 1978 and 1980 as portions of other projects. For a nominal investment, the program has continued for over six years and is now beginning to provide meaningful test results. For the first time, shipyards have access to data which can be used to evaluate the various generic coating systems presently on the market. Even though the state-of-the-art has progressed since the program was initiated, many of the products are still available as originally formulated or with improved formulations. Stated another way, shipyards now have data which can be used to predict actual coatings performance. As an added benefit, accelerated test methods are presented which can be used to screen candidate coating systems.

Project Results

1.1 Project Overview

This project is a continuation of two performance test programs which began in 1978 and 1980. The first program was entitled "Marine Coatings Performance for Different Ship Areas" and the second was “Cleaning of Steel Assemblies and Shipboard Touch-Up Using Citric Acid”. Both programs included accelerated laboratory testing techniques such as Salt Fog Cabinets and Light-and-Water-Exposure Apparatus and exterior Test Fence Exposure (45 Degrees South) . This report contains the results of the exterior test fence performance after six years of exposure and attempts to correlate exterior performance with some attributes which can be tested by accelerated laboratory test methods. In addition, various abrasives were used to prepare the substrate of some panels prior to coatings application. Four different types of abrasives were used to prepare panels to which various inorganic zinc primers were applied, and two types were used to prepare the panels to which the generic coating systems were applied. The four abrasives were silica sand, mineral sand, coal slag, and GL-40 steel grit. The two types were mineral sand and GL-40 steel grit.

This report should not be used to qualify, disqualify, compare or select a given supplier or system. The materials used were standard, off-the-shelf materials with no controls exercised to insure that the materials were acceptable prior to use.In addition, no attempt was made to control film thickness to meet manufacturer’s recommendations. In some cases, the products tested have been reformulated and/or product designation changed. Some are no longer manufactured or recommended for use as tested. The purpose for presenting the data is to compare genera1 performance of various generic materials and to compare the results to laboratory testing. It must also be remembered that shipyard production influences have not been factored into performance.

The results and conclusions of these programs are as follows:

1. Careful selection of laboratory test methods and evaluation parameters, to simulate service conditions, can serve as a screening method for candidate coatings.

2. Most generic exterior coating systems continue to provide protection to the steel substrate after 6 1/2 years exposure even though some topcoats have failed.

3. The degree of undercutting protection provided by inorganic zinc primer does not appear to be film thickness dependent. Of the 56 systems tested, only 16 had any degree of undercutting. The film thickness of the primers with undercutting and without undercutting varied from 1.8

to 5.8 roils.

4. More chlorinated rubber systems failed than any other generic type tested. This supports the actual case history analysis of "Marine Coatings Performance for Different Ship Areas" study which found that inorganic zinc with epoxy topcoats outperformed inorganic zinc with chlorinated rubber topcoats.

5. Abrasive selection has no measurable impact on overal1 coating performance.

6. Exterior fade and chalk of topcoats roughly correlate with Light-and-Water Exposure Cabinets.

7. Salt Fog screening tests can be used for inorganic zinc primer provided the primer is allowed to age in an exterior environment for at least sixty days prior to testing.

8. Primers applied over citric acid cleaned steel performed as well as, or superior to, the same primer applied over abrasive blast cleaned steel.

9. Of the primers tested, the two component inorganic zinc provides the best corrosion protection.

1.2 Cost Savings

Exact cost savings are difficult to define; however, a properly designed test program can screen proposed candidate paints and identify potentially poor performers. The cost of such a program may seem expensive (approximately $5,000.00) until it is remembered just how expensive it is to replace the freeboard paint system of a ship at guarantee survey time; 5 to 6 figure range. It must be stressed that any test program be properly designed and controlled. Placing steel plates painted with different materials in the steel storage yard and checking at irregular intervals is not a test program.

1.3 Continued Research

The test fence program should be continued to determine at what point significant generic system or primer failures occur and the steel begins to deteriorate.

The Salt Fog Cabinet and the Light-and-Water Apparatus subject the coating system to different environmental conditions, namely salt spray and ultraviolet/water shock treatments respectively. A test program should be devised to test the synergistic affects of a combination of these effects on a coating system. One approach could be to expose coating systems first in a Light-and-Water Test Apparatus for 200 hours and then in a Salt Fog Cabinet for 100 hours. The test panels would then be cycled between test environments until coating failure. Simultaneously, control environments until coating failure. Simultaneously, control panels with the same system could be tested in each apparatus without cycling or removal. Results could then be compared.

2.0 Details of the Program

2.1 Marine Coating System Performance Study

This portion of the test program was initially formulated to verify or support actual case histories collected as a part of the original "Marine Coating Performance Study". The exterior freeboard was selected as a representative area. This area was chosen because of the availability of the test environment and the possible potential of collecting adequate numbers of historical data.

2.1.1 Systems Tested

Table I includes the Paint Systems tested. In general, ten suppliers submitted wet samples of paint which were product matches for the generic description of the requested systems. Five primary systems were compared wit-h some alternates being tested. The primer in all cases was a solvent based, (alkyl) inorganic zinc. The topcoats were polyamide epoxy intermediate with and without topcoats of either aliphatic polyurethane, silicone alkyd, or alkyd. The other systems had intermediate and topcoats of either chlorinated rubber or vinyl. The film thicknesses listed are actual film thickness measurements.

2.1.2 Test Panel Preparation

The steel panels used for testing were ASTM A-36, 6" X 18" X 1/4" hot rolled plate. All panels were abrasive blasted to Steel Structures Painting Council Surface Preparation Standard, ssPc-SP1O, "Near White". Two types of abrasives were used to prepare the panels-mineral sand and steel grit. Some systems were applied over both mineral sand and steel grit prepared substrates and some were only applied over steel grit blasted surfaces. A senior laboratory technician skilled in paint application applied each coating. Material application data sheets supplied by each manufacturer were used to determine thinning, application and overcoat time requirements. No special procedures nor special considerations were granted, and no controls were exercised to precisely control film thickness.

2.1.3 Test Environment

The prepared and painted test panels were exposed on an exterior test rack at 45 South in Jacksonville, Florida less than 100 yards from the St. John’s River. The St. John’s River at this location has a salt content very similar to the Atlantic ocean which is less than 2 miles away.

2.1.4 Evaluation Techniques

Panels were evaluated for rust, chalk, gloss, cracking, blistering and checking using the following ASTM Standards:

Evaluating the Degree of Rust	ASTM D610
Evaluating the Degree of Chalk	ASTM D659
Evaluating the Degree of Gloss	ASTM D523
Evaluating the Degree of Checking	ASTM D660
Evaluating the Degree of Cracking	ASTM D661
Evaluating the Degree of Blistering	ASTM D714

2.1.5. Exterior Generic Coating System Test Results

Table I contains the results of these tests, Figures 2.1 and 2.3 thru 2.8 contain photographs of representative test panels. As seen from the test data, differences in chalking and percent change in gloss are easily detected. These results generally agree with other published test results. Epoxies chalk more than chlorinated rubbers and chlorinated rubbers chalk more than aliphatic polyurethane. It can also be seen that in the one case tested, aliphatic polyurethanes outperform aromatic polyurethanes. Most systems continue to provide adequate corrosion protection.

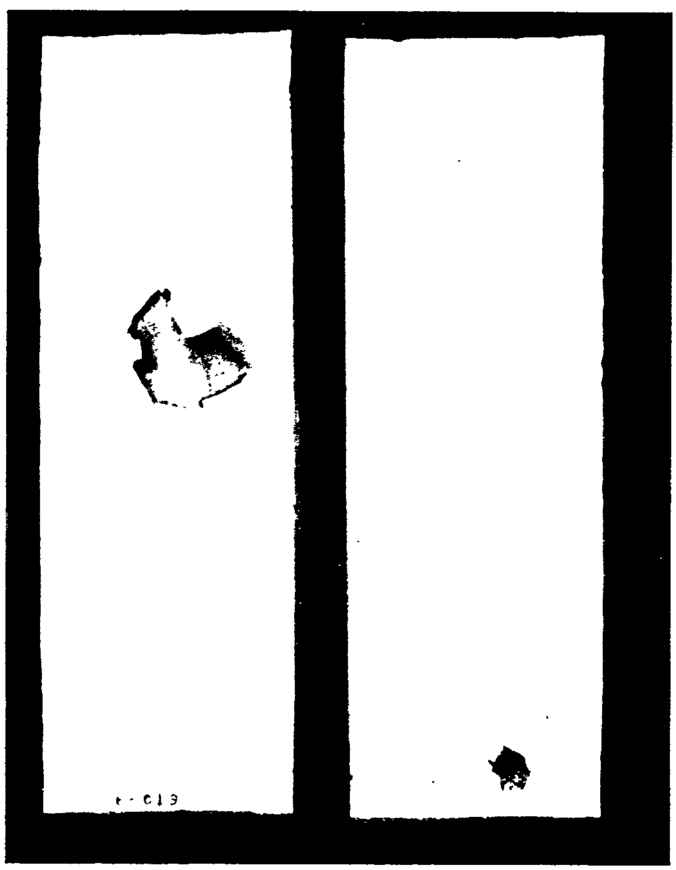


Figure 2.1: Vinyl Delamination from Primer

Table I: Various Generic Coating Systems Exposed On Exterior Test Rack (45 South)

Generic Type	Supplier	Abrasive Type	Prduct No.	Film Thickness	Rating (6.5 Yrs.)
Inorganic zinc	Ameron	GL-40 Steel Grit	D-6	5.0	10-Rust Gloss Not Evaluated
Synthetic Tiecoat			54TC	1.5	Flat Finish
vinyl Copalymer		Mineral Sand	99	1.1	10-Rust Gloss Not Evaluated
vinyl Copolymer			99	3.6	Flat Finish
Inorganic Zinc	Ameron	GL-40 Steel Grit	D-6	5.0	10-Rust 8-Erosion
Polyamide Epoxy			66	3.0	
Polyamide Epoxy		Mineral Sand	66	4.0	10-Rust 8-Erosion
Inorganic zinc	Ameron	GL-40 Steel Grit	D-6	4.0	10-Rust 6-Chalk @ 1 Year
Polyamide Epoxy			383	2.5	87% Loss in G1OSS @ 3 Months
Polyamide Epoxy		Mineral Sand	383	5.5	10-Rust 6-Chalk @ 1 Year 87% Loss in G1OSS @ 5 Months
inorganic Zinc	Ameron	GL-40 Steel Grit	D-6	4.3	10-Rust 9 .5-Chalk @ 1 Year
Polyamide Epoxy			71	1.5	50% Loss in Gloss @ 1 Year
Silicone Alkyd			5403	2.6	
Silicone Alkyd		Mineral Sand	5403	1.0	l0-Rust 9-Chalk @ 1 Year 50% Loss in Gloss @ 1 Year
Inorganic zinc	Ameron	GL-40 Steel Grit	D-6	4.6	10-Rust 9-Chalk @ 1 Year
Polyamide Epoxy			71	1.9	46% Loss in G1oss @ 1 Year
Aliphatic Polyurethane		Mineral	2119	1.7	10-Rust
Aliphatic Polyurethane		Sand	2119	3.7	1/16"Undercut @ Scribe 9-Chalk @ 1 Year 41% loss in Gloss @ 1 Year

Table I (con't)

Inorqanic Zinc	Ameron	G1-40 Steel Grit	D-6	5.0	lo-Rust 1/16" Undercut @ Scribe
Chlorinated Rubber			2015	2.0	8-chalk @ 1 Year 55% Loss in Gloss @ 1 Year
Chlorinated Rubber		Mineral Sand	2029	1.8	10-Rust 1/16" undercut @ Scribe
Chlorinated Rubber			2029	3.0	8-Chalk 70% Loss in Gloss @ 1 Year
Inorganic Zinc	Carboline	GL-40 Steel Grit	CZll	6.0	10-Rust 6-Chalk
Vinyl Copolymer Tiecoat			935TC	2.0	81% Loss in Gloss @ 1 Year. Topcoat Delamination @ 45 Months. See Photo 2.1
vinyl Copolymer		Mineral Sand	938	1.5	10-Rust 6-Chalk
vinyl Copolymer			938	4.0	81% Loss in Gloss @ 1 Year. Topcoat Delamination @ 45 Months. See Photo 2.1
Inorganic zinc	Carboline	GL-40 Steel Grit	CZll	3.0	10-Rust 8-Chalk
Polyamide Epoxy			191HB	6.2	77% Loss in Gloss @ 1 Year
Mod. Medium Oil Alkyd			GP-62	1.8	
Mod. Medium Oil Alkyd			GP-62	0.8	
Inorganic Zinc	Carboline	Mineral Sand	CZll	7.8	10-Rust 9-Chalk
Polyamide Epoxy			191HB	6.2	30% Loss in Gloss @ 1 Year
Aliphatic Polyurethane			132	4.0	
Aliphatic Polyurethane			132	4.5	
Inorganic zinc	Carboline	GL-40 Steel Grit	CZll	6.0	Failed @ 24 months 6-Chalk @ 1 Year
Chlorinated Rubber			3630	2.1	95% Loss in Gloss @ 1 Year
Chlorinated Rubber		Mineral Sand	3630	0.5	Failed @ 24 months 6-Chalk
Chlorinated Rubber			3630	3.0	95% Loss in Gloss @ 1 Year. See Photo 2.4 (Right Panel #6-024)

Table I (con't)

Inorganic zinc	Devoe	GL-40 Steel Grit	304	5.0	10-Rust 9-Chalk @ 1 Year 6% Loss in G1OSS @ 1 Year. 64% @ 2 Years
vinyl Tiecoat			MD4368	0.8	
vinyl Acrylic			MD4361	1.0	
vinyl Acrylic		Mineral Sand	MD-4361	3.0	10-Rust 1/32" undercut @ scribe 9-Chalk 3% Loss in Gloss @ 1 Year. 60% @ 2 Years
Inorganic zinc	Devoe	GL-40 Steel Grit	304	7.0	10-Rust 4-Chalk 4-Erosion 88% Loss in Gloss @ 2 Months. Pinholes From Topcoat Erosion.
Polyamide Epoxy			224	7.8	
Inorganic Zinc	Devoe	Mineral Sand	304	6.0	Complete Failure of Topcoat. Cracking/ Alligating. See Photo No. 2.5.
Polyamide Epoxy			224	7.0	
Silicone Alkyd			MD3925	4.0	lo-Rust
Silicone Alkyd			MD3925	8.9	
Inorganic Zinc	Eevoe	GL-40 Steel Grit	304	5.0	lo-Rust 8-Chalk @ 1 Year 96% Loss Of G1oss @ 10 14Months.Scme Under-cutting @ Scribe & Pinholes from Erosion.
Polyamide Epoxy			2 2 4	8.0	
Acrylic Epoxy		Mineral Sand	229	8.0	
Inorganic zinc	Hempel	GL-40 Steel Grit	1570	3.6	10-Rust 2-Chalk @ 9 Months 96% Loss in G1oss @ 4 Months
Polyamide Fcw?			HB4520	3.0	
Polyamide Epoxy			5534	3.8	
Inorganic zinc	Henpel	GL-40 Steel Grit	1570	3.6	lo-Rust 8-Chalk @ 1 Year 84% Loss in Gloss @ 7 Months
Polyamide Epoxy			HB4520	3.5	
Alkyd			5214	3.5	

Table I(con't)

Inorganic Zinc	Hempel	GL-40 Steel Grit	1570	3.6	l0-Rust 9-Chalk @ 1 Year
Polyamide Epoxy			HB4520	3.8	31% Loss in Gloss @ 1 Year
Silicone Aluminum (High Heat)			5372	3.0	
Inorganic zinc	Imperial	GL-40 Steel Grit	555	5.3	lo-Rust 6-Blisters (Few) @
vinyl Tiecoat			777	3.4	20 Months 8-Chalk @ 1 Year
vinyl Topcoat			321	3.0	Gloss Not Evaluated, Flat Finish.
Inorganic Zinc	Imperial	GL-40 Steel Grit	555	5.0	10-Rust 4-Chalk @ 9 Months
Polyamide Epoxy			1200	6.8	1/8" Undercut @ Scribe Gloss Not Evaluated, Flat Finish.
Inorganic zinc	Imperial	GL-40 Steel Grit	555	4.2	lo-Rust 6-Chalk @ 1 Year
Polyamide Epoxy			1200	9.6	70% Loss in Gloss @ 1 Year.
Alkyd			88	5.2	
Inorganic zinc	Imperial	GL-40 Steel Grit	555	4.5	10-Rust 8-Chalk @ 1 Year
Polyamide Epoxy			1200		60% Loss in Gloss @ 1 Year, However No
Silicone Alkyd			84		Change in Gloss for 2nd Year.
Inorganic zinc	Imperial	GL-40 Steel Grit	555	4.4	10-Rust 9.5-Chalk @ 1 Year
Polyamide Epoxy			1200	5.4	1/16" Undercut @ Scribe 19% Loss in Gloss @
Aliphatic Polyurethane			1001	2.1	1 Year.
Inorganic zinc	Imperial	GL-40 Steel Grit	555	4.7	lo-Rust 8-Chalk @ 1 Year
vinyl Tiecoat			777	2.9	1/8" Undercut @ Scribe 49% Loss in Gloss @
Chlorinated Rubber (Acrylic)			890	1.9	1 Year.

Table I (con't)

Inorganic Zinc	International	GL-40 Steel Grit	2410/11	2.0	lo-Rust 8-Chalk @ 1 Year
vinyl			846	1.9	79% Loss in Gloss @
vinyl Acrylic			3508	1.5	1 Year.
vinyl Acrylic		Mineral Sand	3508	1.0	10-Rust 8-Chalk @ 1 Year 77% Loosing Gloss @ 1 Year.
Inorganic zinc	International	GL-40 Steel Grit	2410/11	2.5	9-Rust 1/4" undercut @ Scribe
Vinyl Wash Primer			1757/58	1.0	9-Chalk @ 1 Year 69% Loss in G1oss @
Aliphatic Polyurethane			2202/14	2.5	1. Year.
Aliphatic Polyurethane		Mineral Sand	2202/14	3.5	9-Rust. 9-Chalk @ 1 Year 72% Loss in G1oss @ 1 Year. Total Topcoat Delamination @ 5 Years 3 1/2" Underecut. See Photo 2.6.
Inorganic zinc	International	GL-40 Steel Grit	2410/11	2.3	9-Rust 4-Checking. See 2.6.
Vinyl Wash Primer			1757/58	1.0	9-Chalk @ 1 Year 40% Loss Gloss @
Aromatic Polyurethane			859	2.5	1 Year.
Aromatic Polyurethane		Mineral Sand	859	2.0	9-Rust 4-Checking 9-Chalk @ 1 Year. 39% Loss in Gloss @ 1 Year.
Inorganic zinc	International	GL-40 Steel Grit	2410/11	2.0	10 Rust-Pinholes from erosion of topcoat.
Polyamide Epoxy			8967/ 1539	16.0	4-Chalk @ 3 Months. 80% Loss in G1oss @ 3 Months.
		Mineral Sand			lo-Rust 4-Chalk @ 4 Months. 87% Loss in G1oss @ 3 Months.
Inorganic zinc	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50	1.8	lo-Rust 1/32" Undercut @ Scribe
vinyl			5DR5	1.6	2-Chalk @ 9 Months.
vinyl			5DW2	2.6	Gloss Not Evaluated, Flat Finish.

Table I (con't)

Inorganic Zinc Polyamide Epoxy Polyamide Epoxy	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 40AH22 513-17	1.6 6.2 2.7	10-Rust . 4-Chalk @ 5 Months. Some Checking 91% Loss in Gloss @ 1 Year.
Inorganic zinc Polyamide Epoxy Alkyd Tiecoat Alkyd Topcoat	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 40AH22 28DR105 5010-16	1.2 6.2 2.7 4.1	10-Rust 9-Chalk @ 1 Year Some Checking 80% Loss in G1oss @ 1 Year.
Inorganic zinc Polyamide Epoxy Polyvinyl Chloride	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 40AH20 5DW2	1.2 6.3 4.2	10-Rust Topcoat Delaminated @ 44 Months. Topcoat Applied in Error.
Inorganic zinc Chlorinated Rubber Chlorinated Rubber	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 548-16 548-16	1.1 2.0 3.5	lo-Rust 5-Chalk @ 5 Months Gloss Not Evaluated, Flat Finish. Some Checking.
Inorganic zinc Vinyl vinyl vinyl	Mobil	GL-40 Steel Grit Mineral Sand	13F12 80R8 83F34 80F34	2.2 0.7 5.3 3.2	10-Rust 1/4" Undercut @ Scribe 4-Chalk @ 1 Year. 90% Loss in Gloss @ 9 Months. 10-Rust 4-Chalk @ 1 Year. 90% Loss in Gloss @ 9 Months.
Inorganic zinc Polyamide Epoxy Polyamide Epoxy	Mobil	GL-40 Steel Grit Mineral Sand	13F12 89F12 84F34	2.5 6.5 1.6	lo-Rust Some Erosion of Topcoat 4-Chalk @ 5 Months. 90% Loss of Gloss @ 4 Months. 10-Rust 4-Chalk @ 5 Months. 91% Loss of Gloss @

Table I (con't)

Inorganic Zinc	Mobil	GL-40 Steel Grit	13F12	2.5	lo-Rust 9-Chalk @ 1 Year.
Polyamide Epoxy			89F15	9.0	71% Loss in Gloss @ 1 Year.
Alkyd		Mineral Sand	20F34	1.5	lo-Rust 8Chalk @ 1 Year. 68% Loss Gloss @ 1 Year.
Inorganic zinc	Mobil	GL-40 Steel Grit	13F12	2.4	10-Rust 9-Chalk @ 1 Year.
Polyamide Epoxy			89F15	9.2	40% Loss in Gloss @ 1 Year.
Aliphatic Polyurethane		Mineral Sand	40W9	2.8	10-Rust 8-Chalk @ 1 Year. 40% Loss in Gloss @ 1 Year.
Inorganic zinc	Mobil	GL-40 Steel Grit	13F12	2.0	lo-Rust 9-Chalk @ 1 Year.
Polyamide Epoxy			89F15	8.3	46% Loss in G1oss @ 1 Year.
Water Borne Acrylic		Mineral Sand	42F34	1.5	lo-Rust 9- Chalk @ 1 Year. 46% Loss in Gloss @ 1 Year.
Inorganic Zinc	Mobil	GL-40 Steel Grit	13F12	2.2	10-Rust,Blistering & Complete Failure of
Chlorinated Rubber			27F15	4.0	Topcoat @ 56 Months 9-Chalk @ 1 Year.
Chlorinated Rubber			28F34	2.8	71% Loss of Gloss @ 1 Year. See Photo 2.8.
		Mineral Sand			10-Rust, No Topcoat Failure. 8- Chalk @ 1 Year. 70% Loss in Gloss @ 1 Year.
Inorganic zinc	Napko	GL-40 Steel Grit	1375	4.7	10-Rust 1/8" undercut @ Scribe
Copolymer Tiecoat			1340	1.8	9-Chalk @ 1 Year. Gloss Not Evaluated,
vinyl Topcoat			5452	2.8	Flat Finish.
Inorganic zinc	Napko	GL-40 Steel Grit	1375	4.5	lo-Rust 9-Chalk @ 1 Year.
Vinyl			5437	2.3	Gloss Not Evaluated,
vinyl			5452	2.3	Flat Finish.

Table I (con't)

Inorganic zinc Catalyzed Epoxy	Napko	GL-40 Steel Grit	1375 5802	5.5 5.2	lo-Rust 1/32" Undercut @ Strike 4-Chalk @ 7 Months. 81% Loss in Gloss @ 2 Months.
Inorganic zinc Polyamide Epoxy Alkyd	Napko	GL-40 Steel Grit	1375 5616 4318	4.9 2.4 1.0	10-Rust. 1/32" Undercut @ Scribe 8-Chalk @ 1 Year. 90% Loss in Gloss @ 9 Months.
Inorganic zinc Chlorinated Rubber Chlorinated Rubber	Napko	GL-40 Steel Grit	1375 8-4137 8-4137	5.8 3.0 2.6	lo-Rust 1/4" Undercut @ Scribe 9-Chalk @ 1 Year. 74% Loss of Gloss @ 1 Year.
Inorganic zinc Polyamide Epoxy Polyurethane	Napko	GL-40 Steel Grit	1375 5616 5909	5.'7 1.6 2.5	lo-Rust 1/4" Undercut @ Scribe 9.5-Chalk @ 1 Year. 15% Loss of Gloss @ 1 Year.
Inorganic zinc High Build Polyurethane Polyurethane	Napko	GL-40 Steel Grit	1375 8-4144 5909	5.4 3.4 3.5	Topcoat Delaminated from Inorganic Zinc @ 18 Months. 9.5-Chalk @ 1 year. 17% Loss of Gloss @ 1 Year. See Photo 2.4 (Left Panel # 6-109)
Inorganic zinc Vinyl Wash Primer vinyl	Porter	GL-40 Steel Grit	351 1799 3710	3.0 0.5 2.0	lo-Rust 2-chalk @ 9 Months. Gloss Not Evaluated, Flat Finish.
Inorganic zinc Vinyl Wash Primer Aliphatic Polyurethane	Porter	Mineral Sand	351 1799 4674	3.0 0.5 2.0	lo-Rust 1/32" Undercut @ Scribe 9.5-Chalk .@ 1 Year. 23% Loss of Gloss @ 1 Year.
Inorganic zinc High Build vinyl	Sherwin-Williams	GL-40 Steel Grit	A618l/B69 B69A26	(Total DFT)	10-Rust l/16" .Undercut @ Scribe 6-Chalk @ 1 Year. G1poss Not Evaluated, Flat Finish.

Table I (con't)

Inorganic zinc Epoxy	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69W70	7.7 (Total DFT)	lo-rest 1/3" Undercut @ Scribe 4-Chalk @ 7 Months. 91% loss of Gloss @ 2 Months.
Inorganic zinc Epoxy Alkyd	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69N70 B53W10	11.5 (Total DFT)	7-Rust 1 1/2" Undercut @ Scribe 6-Chalk @ 1 Year. 89% Loss Of G1oss @ 7 Months.See Photo 2.3
Inorganic zinc Epoxy Aliphatic	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69N70 F63W13	14 (Total DFT)	9-Rust 1/2" Undercut @ Scribe 8-Chalk @ 1 Year. 62% Loss of G1oss @ 1 Year.
Inorganic Zinc Chlorinated Rubber Chlorinated Rubber	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69W17 B69W17	8.5 (Total DFI)	lo-Rust 1/32" Undercut @ Scribe 9-Chalk @ 1 Year. 67% Loss of G1oss @ 1 Year.
Modified Inorganic zinc Polyamide Epoxy Polyamide Epoxy	Sigma	GL-40 Steel Grit	7552 7430/2190 7425/7000	2.3 5.1 3.6	10-Rust Alligating/Pinholes 56 Months. Complete Topcoat Failed @ 66 Months. 2-Chalk @ 5 Months. 95% Loss of Gloss @ 5 Months.
Modified Inorganic Zinc Polyamide Epoxy Silicone Alkyd	Sigma	GL-40 Steel Grit	7552 7430/2190 7238/7000	2.3 6.6 0.7	lo-Rust 1/32" Undercut @ Scribe 9-Chalk @ 1 Year. 56% Loss Of G1oss @ 1 Year.
Modified Inorganic zinc Polyamide Epoxy Aliphatic Polyurethane	Sigma	GL-40 Steel Grit	7552 7430/2190 7520/7000	2.6 7.4 1.9	lo-Rust 4-Checking 9.5-Chalk @ 1 Year. 7% Loss of Gloss @ 1 Year.
Modified Inorganic zinc Chlorinated Rubber Chlorinated Rubber	Sigma	GL-40 Steel Grit	7552 7311/200 7310/200	2.5 3.5 3.4	lo-Rust 4-Checking 8-Chalk @ 1 Year. 60% Loss of G1oss @ 1 Year.

2.1 .5.1 Corrosion Protection

With minor exceptions, most of the systems tested continue to provide adequate corrosion protection as concerns ASTM Rust Grades. The primary difference seems to be in the degree of undercutting even though no precise conclusions can be drawn. The following Table summarizes the results:

Table II: Summary of Undercutting

	Undercutting	Percent of Systems With Undercutting
Inorganic Zinc Epoxy	4 of 12 Systems Tested	33%
Inorganic Zinc Epoxy Alkyd	3 of 11 Systems" Tested	27%
Inorganic Zinc Epoxy Polyurethane	4 of 7 Systems Tested	57%
Inorganic Zinc Vinyl	5 of 10 Systems Tested	50%
Inorganic Zinc Chlorinated Rubber	4 of 8 Systems Tested	50%

2.1.5.2. Chalk Ratings

Table I contains chalking information. In addition, exterior test results at 6,12 and 18 months compared to the same systems evaluated for 1000 hours in a carbon arc Light-and-Water Apparatus are contained in the following table:

Table III: Chalk Evaluation Results

	Test Fence** 6 Months	1 year	18 Months	Test Apparatus 1000 Hours
Epoxy	4.1	4.1	3.9	4.0
Alkyd	8.8	7.9	8.0	8.7
Silicone Alkyd	9.3	9.1	9.1	9.1
Aliphatic Polyurethane	9.5	9.1	8.1	9.4
Vinyl	8.3	6.1	6.2	8.0
Chlorinated Rubber	8.5	7.7	5.4	8.8

*Only finish coats are listed
**Average of all systems tested

From these tests, 1,000 hours in the accelerated test chamber appears to approximate six months on the test fence. With most systems, minor change in chalking occurred after six months. The degree of chalking by generic type generally follows the accepted rules for chalking except for the aliphatic polyurethane. Of the materials tested, the silicone alkyd materials outperformed the polyurethane.

2.1.5.3 Gloss Results

Table I presents gloss information as a percent loss of gloss with time. It was necessary to normalize the data in this manner to provide meaningful results because of the wide variance of initial gloss readings. The graphs in Figure 2.2 also compare loss of gloss with time under both accelerated conditions and after exterior test fence exposure. These are selected examples and not averages of all systems tested. One year on the test fence provided reasonable correlation with 1000 hours in the test chamber.

2.1.5.4 Overall System Performance

Of the systems tested, the only generic type supplied from two different sources which failed by the same mechanism was the chlorinated rubbers. This may be coincidence; however, the results do somewhat correlate with the original performance study (Reference 3).In that study, chlorinated rubbers did not appear to perform as well as some other generic types. Vinyl wash primer with polyurethanes and high build polyurethane both failed in this test program; however, most suppliers no longer recommend these systems. The epoxy and epoxy/alkyd systems which failed at 66 months may be indicative of the useful life of these generic types; however, numerous other epoxy systems are continuing to perform. Table IV summaries the results of total system failures.

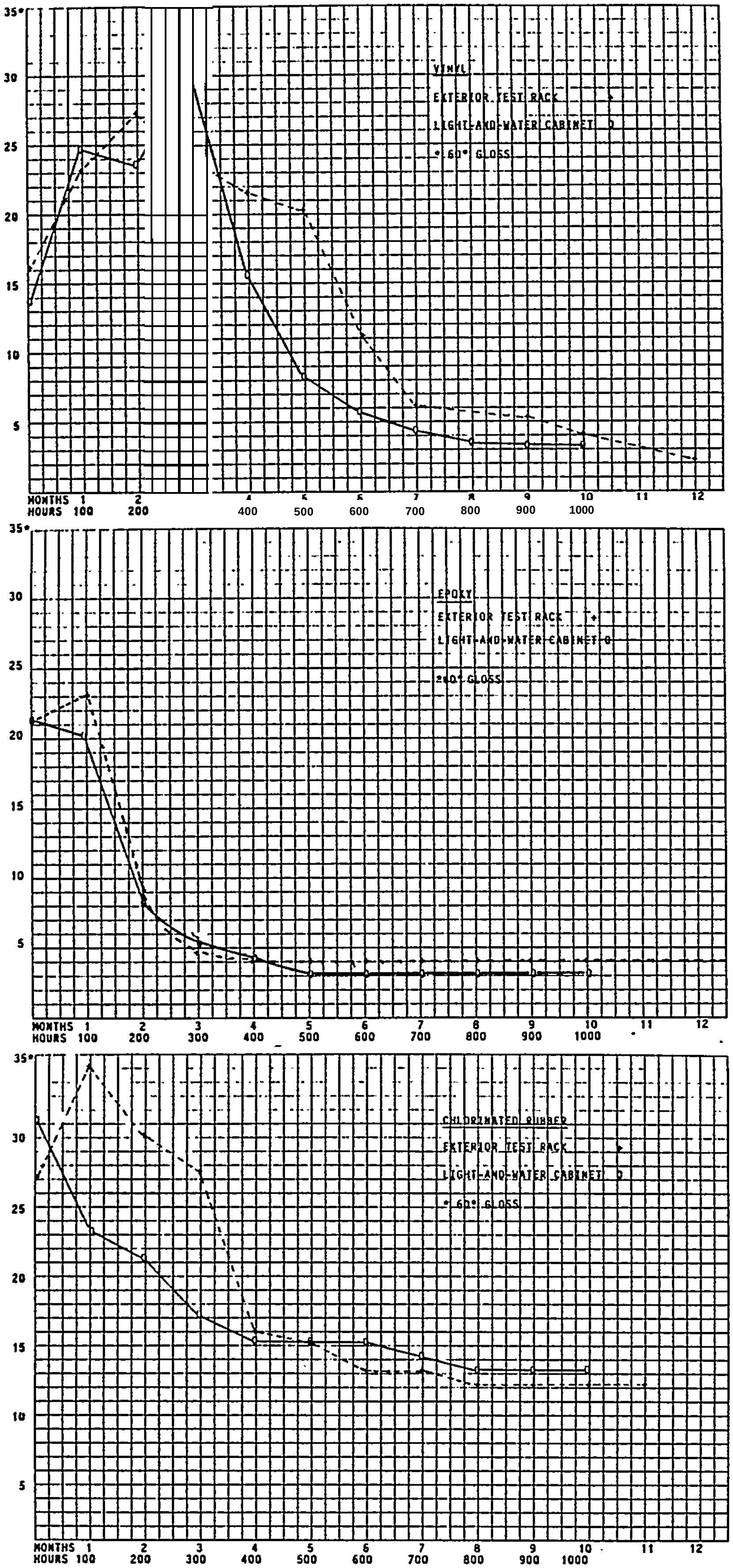


Figure 2.2: Graphs of Gloss Results

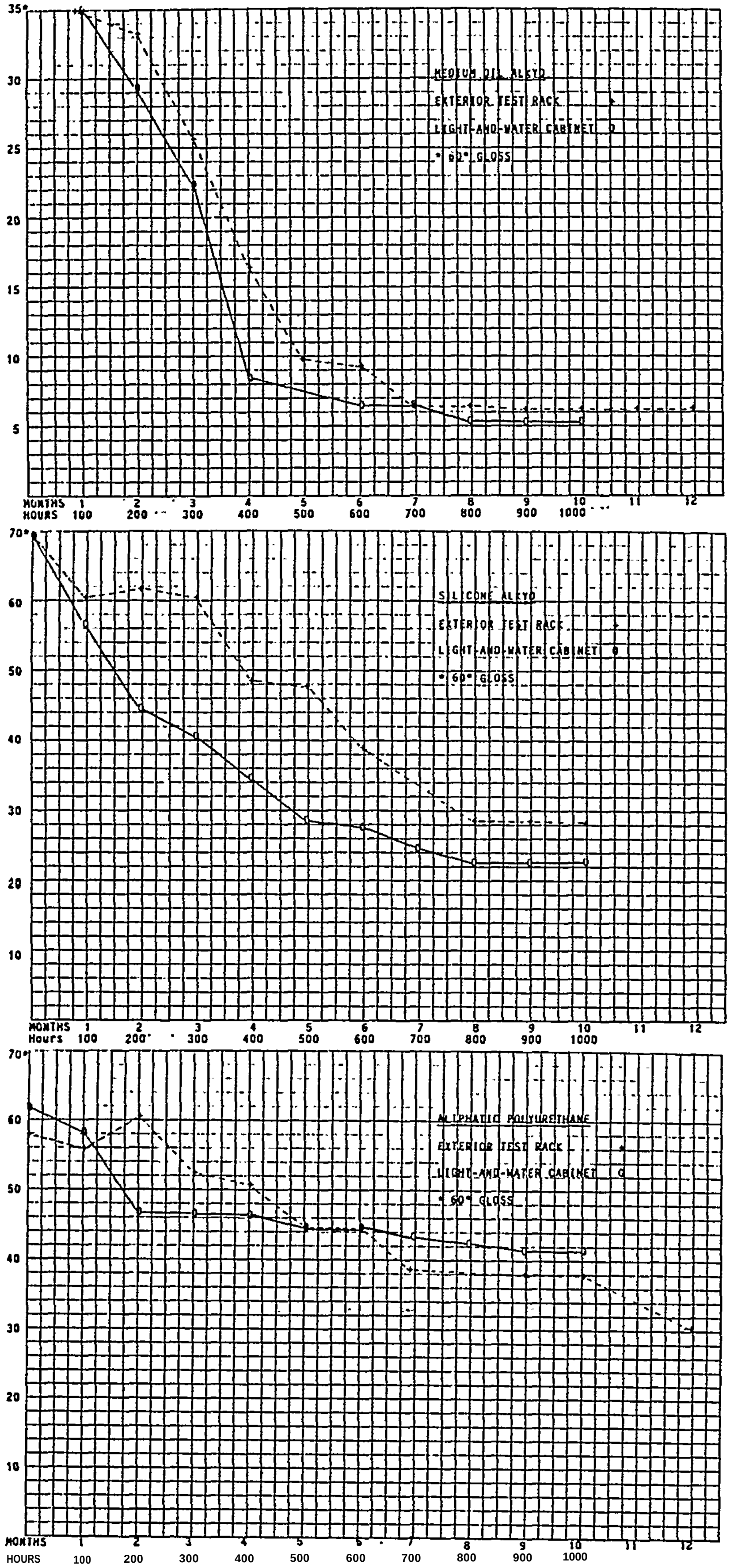


Figure 2.1: (con't)

Table IV: Total System Failure Modes

Generic System	Systems Failed/Tested	Time	Failure Mode
Epoxy/Silicone Alkyd	l o f 4	66 months	Checking(Photo 2.5)
Epoxy/Alkyd	l o f 7	66 months	Delamination from Scribe (Photo 2.3)
Vinyl Wash Primer/ Aliphatic Polyurethane	l o f l	60 months	Undercutting from Scribe (Photo 2.6)
High Build Urethane/ Aliphatic Polyurethane	l o f l	18 months	Delamination of Topcoat from Primer
Vinyl Wash Primer\ Aromatic Polyurethane	l o f l	66 months	Checking(Photo 2.7)
Chlorinated Rubber	2 o f 8	l@ 24 months l@ 56 months	Topcoat Delamination Complete Topcoat Failure(Photo 2.4 & 2.8)
Epoxy	1 of 10	56 months	Alligating\checking
Vinyl	l o f 9	45 months	Topcoat Delamination (Photo 2.1)

*All systems primed with inorganic zinc.

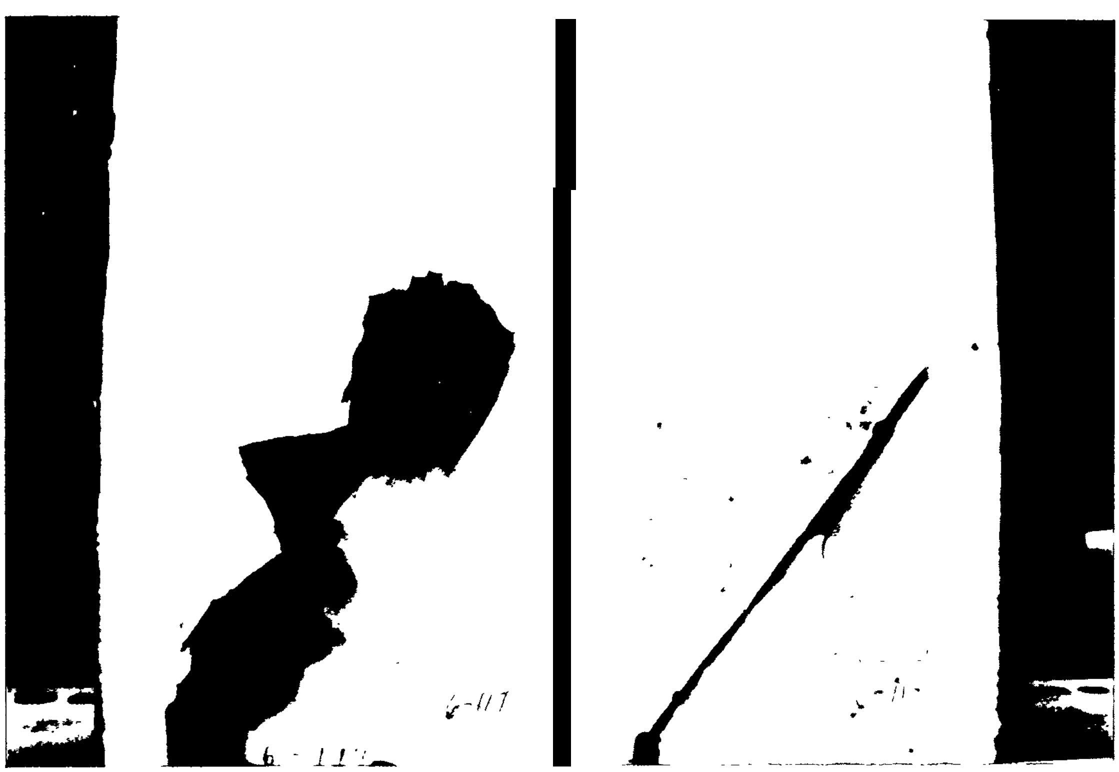


Figure2.3: Undercutting of Epoxy/Alkyd Coating System

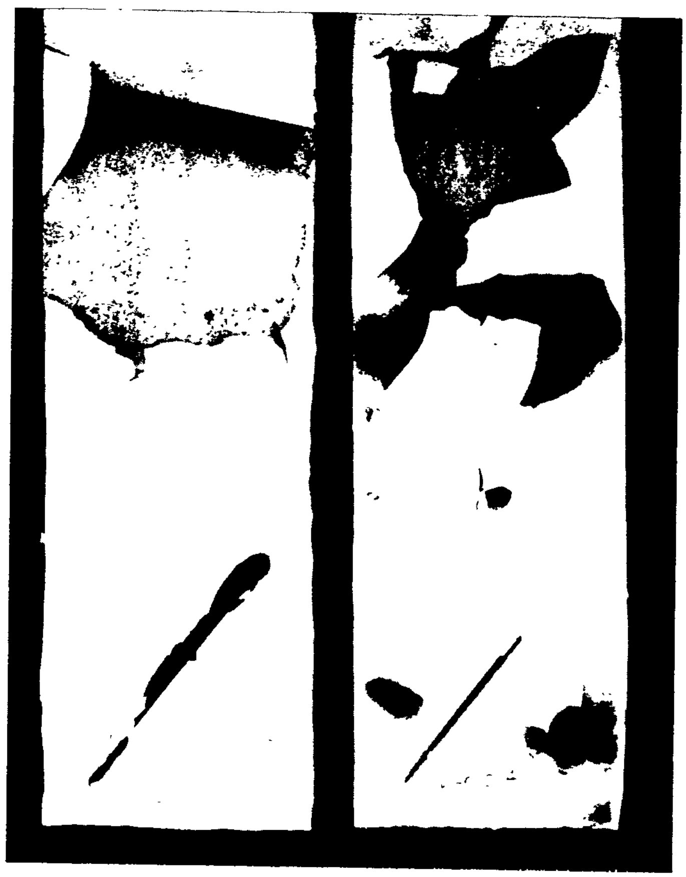
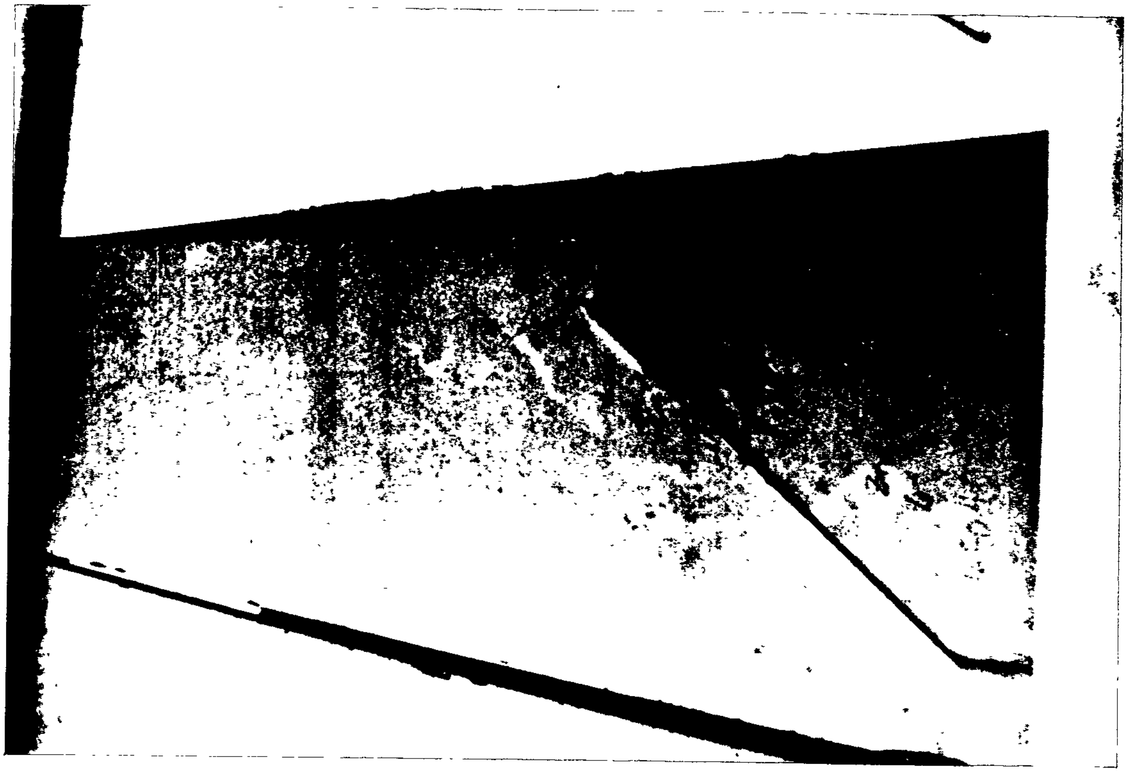
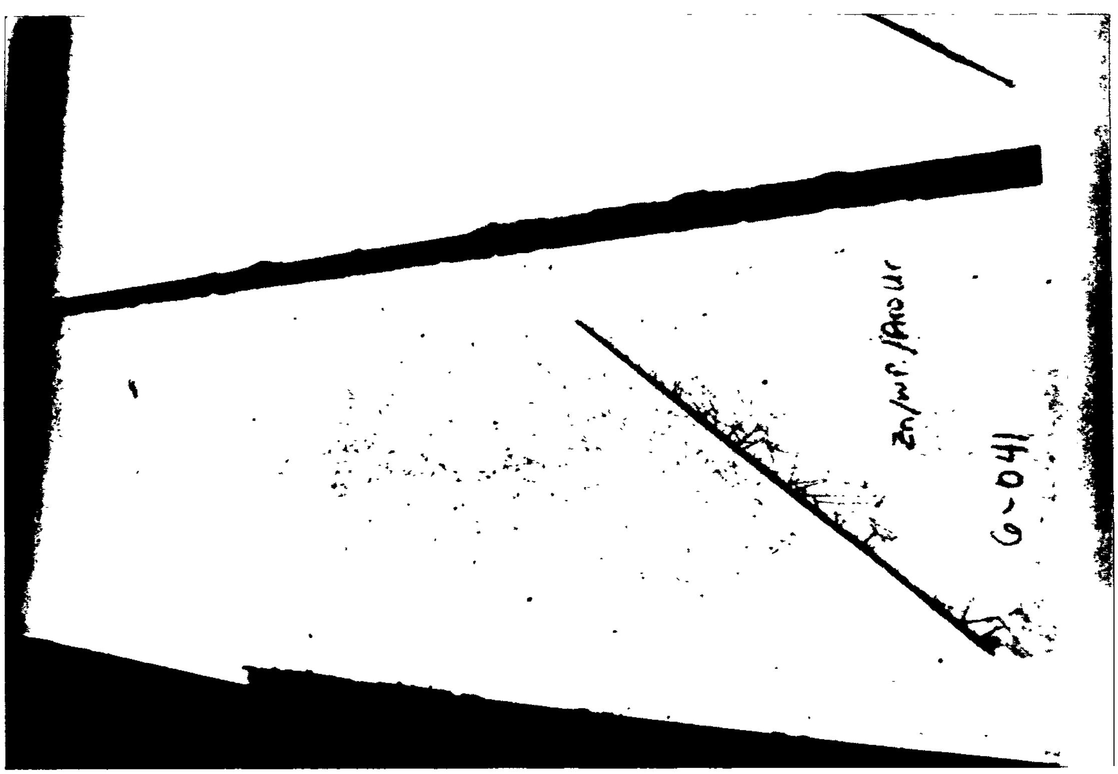


Figure 2.4: Failure Mode of High Build Polyurethane and Chlorinated Rubber Panels





2.2 Citric Acid Cleaned Verses Abrasive Blast Cleaned Panels

There were two different series of exterior test fence exposures of tested primers. The first was a direct comparison of primers applied to both citric acid cleaned panels and abrasive blast cleaned panels. The second was a test to compare citric acid as a touch-up surface preparation technique to the widely used power tool cleaning touch-up technique. The paragraphs which follow discuss each series in detail.

2.2.1 Primer Test

2.2.1.1 Test Panel Preparation

One hundred primers representing seventeen generic types were submitted by ten supplier. Test panels of A-36 steel measuring 6" X 18" were first descaled and then allowed to rust for approximately eight weeks by exposure in an outside industrial, marine environment. Following aged rusting, the panels were divided into two groups. The first group was abrasive blasted to Steel Structures Surface Preparation Standard, SSPC SP 10, "Near White Blast," and the second group was cleaned utilizing a citric acid process. The selected primers were then applied to panels cleaned by each process. Both panels within a set were sprayed at the same time in an effort to duplicate actual film thicknesses. No inhibitors were used with the citric acid process.

2.2.1.2 Test Environment and Evaluation Technique

The resulting primed panels were then placed on the test fence at 45 Degrees South for 66 months. Rust grades were determined in accordance with ASTM D610.

2.2.1.3 Primer Test Results

Table VI contains detail application data and performance rating of each primer tested. There were no difference in the performance of post cure inorganic zincs and only minor differences in the water based inorganic zincs applied over both surface preparation methods. The abrasive blasted primers again showed a slightly inferior performance. The remainder of the other types of zinc rich primers also demonstrated almost identical results. Table V contains a summary the results for some of the generic types of primers. As stated earlier no attempt should be made to compare performance between primers of the same generic type and different suppliers or different generic types without taking into account the actual film thickness of the applied materials and the design purpose of each material.

Table V: Citric Acid/Abrasive Blast Performance Summary

Generic Primer	Average Rust Grade Critric Acid	Average Rust Grade Abrasive Blast
Alkyl Inorganic Zinc	9.6	9.5
One Component Inorganic Zinc	8.2	6.3
Water Based Inorganic Zinc	9.3	8.2
Post Cured Inorganic Zinc	10	9.3
One Component Epoxy Zinc Rich	8.3	7.0
Two Component Epoxy Zinc Rich	8.6	7.0
One Component Epoxy Primer	4.4	3.6
Polyamide Epoxy Primer	5.8	4.9
Polyamine Epoxy Primer	7.5	7.3
Epoxy Ester Primer	7.7	4.5
Alkyd Primer	7.3	6.5
Vinyl Primer	4.7	3.8
Chlorinated Rubber Primer	4.6	5.0

The average performance of all the primers applied over abrasive blasted surfaces was inferior to the performance of those-applied over citric acid. The mean performance of abrasive blast was 6.2, and the mean for citric acid was 7.1. The averaged results are as follows:

	ABRASIVE BLAST	CITRIC ACID
Mean	6.2	7.1
Standard Deviation	3.8	3.4
Variance	14.3	11.6

TABLE VI

Various Generic Primers Applied to Abrasive Blast Cleaned and Citric Acid Cleaned Panels After 66 Months Exposure On Exterior Test Rack (45 Degrees)

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
Alkyd Inorganic Zinc	Ameron	D-9	Abrasive Blast	4.8	9
Solvent Base			Citric Acid	4.8	9
Alkyd Inorganic Zinc	Byco	101	Abrasive Blast	2.8	8
Solvent Base			Citric Acid	2.4	8
Alkyd Inorganic Zinc	Carboline	CZ11	Abrasive Blast	4.2	10
Solvent Base			Citric Acid	4.2	10
Alkyd Inorganic Zinc	Carboline	CW11	Abrasive Blast	1.6	Failed 32 Mo
Solvent Base			Citric Acid	1.4	10 @ 32 Mo
Alkyd Inorganic Zinc	Devoe	304	Abrasive Blast	2.6	10
Solvent Base			Citric Acid	2.6	10
Alkyd Inorganic Zinc	Farboil	114	Abrasive Blast	3.0	9
Solvent Base			Citric Acid	2.7	9
Alkyd Inorganic Zinc	Imperial	555	Abrasive Blast	3.0	10
Solvent Base			Citric Acid	2.7	10
Alkyd Inorganic Zinc	International	QHA027/	Abrasive Blast	4.6	10
Solvent Base		QHA028	Citric Acid	4.7	10
ALKYD Inorganic Zinc	Mobil	13F12	Abrasive Blast	1.8	10
Solvent Base			Citric Acid	1.6	10
Alkyd Inorganic Zinc	Napko	1375	Abrasive Blast	4.1	9
Solvent Base			Citric Acid	4.2	10
Alkyd Inorganic Zinc	Porter	351	Abrasive Blast	2.2	10
Solvent Base			Citric Acid	2.1	10
Modified Alkyd	Devoe	302R	Abrasive Blast	3.2	6
Inorganic Zinc			Citric Acid	3.0	8
One Component	Ameron	160	Abrasive Blast	3.2	9
Inorganic Zinc			Citric Acid	3.2	9
One Component	Ameron	2155	Abrasive Blast	4.1	6
Inorganic Zinc			Citric Acid	3.6	9
One Component	Byco	102SP92	Abrasive Blast	6.8	9
Inorganic Zinc			Citric Acid	6.5	9
One Component	Devoe	306	Abrasive Blast	3.8	4
Inorganic Zinc			Citric Acid	4.0	9
One Component	Devoe	308	Abrasive Blast	1.7	Failed 18 Mo
Inorganic Zinc			Citric Acid	1.4	8 @ 18 Mo
One Component	Devoe	309	Abrasive Blast	2.6	9
Inorganic Zinc			Citric Acid	2.0	9
One Component	Imperial	545	Abrasive Blast	5.1	10
Inorganic Zinc			Citric Acid	3.6	10
One Component	International	NOA200	Abrasive Blast	3.1	Failed 18 Mo
Inorganic Zinc			Citric Acid	3.0	Failed 18 Mo
One Component	Mobil	13G10	Abrasive Blast	2.9	7
Inorganic Zinc			Citric Acid	2.4	10
One Component	Napko	1301	Abrasive Blast	6.0	9
Inorganic Zinc			Citric Acid	5.4	9
Water Based, Self	Ameron	D-4	Abrasive Blast	4.1	10
Cure, Inorganic Zinc			Citric Acid	4.1	10

Table VI (cont'd)

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
Water Based, Self Cure, Inorganic Zinc	Devoe	305	Abrasive Blast	4.3	9
			Citric Acid	3.5	10
Water Based, Self Cure, Inorganic Zinc	Farboil	76	Abrasive Blast	5.0	10
			Citric Acid	4.5	10
Water Based,Self Cure, Inorganic Zinc	International	TQA001/ TQA002	Abrasive Blast	3.1	10
			Citric Acid	3.0	10
Water Based, Self Cure, Inorganic Zinc	Mobil	46F1	Abrasive Blast	4.3	Failed 3 Mo
			Citric Acid	3.8	6
Water Based,Self Cure, Inorganic Zinc	Napko	1371	Abrasive Blast	5.1	10
			Citric Acid	5.3	10
Post Cure, Inorganic Zinc	Ameron	D-3	Abrasive Blast	4.6	10
			Citric Acid	4.3	10
Post Cure, Inorganic Zinc	Napko	1361	Abrasive Blast	3.3	10
			Citric Acid	3.1	10
One Component Epoxy Zinc Rich	Byco	150-1	Abrasive Blast	4.1	8
			Citric Acid	3.6	10
One Component Epoxy Zinc Rich	Imperial	512	Abrasive Blast	3.6	8
			Citric Acid	2.9	9
One Component Epoxy Zinc Rich	International	ETA441	Abrasive Blast	3.0	Failed 3 Mo
			Citric Acid	2.8	5 @ 3 Mo
One Component Epoxy Zinc Rich	Mobil	518F208	Abrasive Blast	4.0	10
			Citric Acid	2.9	10
One Component Epoxy Zinc Rich	Napko	1355	Abrasive Blast	9.4	7
			Citric Acid	9.2	9
One Component Epoxy Zinc Rich	Porter	309	Abrasive Blast	3.4	10
			Citric Acid	3.3	10
Two Component Epoxy Zinc Rich	Byco	150-5	Abrasive Blast	4.5	9
			Citric Acid	4.3	9
Two Component Epoxy Zinc Rich	Farboil	28	Abrasive Blast	2.4	Failed 32 Mo
			Citric Acid	2.3	5
Two Component Epoxy Zinc Rich	Mobil	13F4	Abrasive Blast	2.4	7
			Citric Acid	2.3	9
Two Component Epoxy Zinc Rich	Napko	5614	Abrasive Blast	5.5	9
			Citric Acid	5.4	10
Two Component Epoxy Zinc Rich	Porter	308	Abrasive Blast	3.8	10
			Citric Acid	3.6	10
Organic Zinc, Chlorinated Rubber	Byco	150-7	Abrasive Blast	3.7	8
			Citric Acid	3.7	8
Organic Zinc	Farboil	79 (Mil-P-1048)	Abrasive Blast	3.9	9
			Citric Acid	3.9	9
One Component Epoxy Primer	Ameron	185	Abrasive Blast	2.9	8
			Citric Acid	2.7	10
One Component Epoxy Primer	Byco	150-2	Abrasive Blast	1.7	Failed 5 Mo
			Citric Acid	1.2	Failed 5 Mo
One Component Epoxy Primer	Farboil	1E2546	Abrasive Blast	1.7	Failed 3 Mo
			Citric Acid	1.3	Failed 3 Mo
One Component Epoxy Primer	Imperial	1215	Abrasive Blast	2.3	Failed 13 Mo
			Citric Acid	1.9	4 @ 13 Mo
One Component Epoxy Primer	International	NEA200	Abrasive Blast	2.8	8
			Citric Acid	2.6	8

TABLE VI(con't)

One Component Epoxy Primer	Napko	1340	Abrasive Blast	2.6	10
			Citric Acid	2.6	10
Polyamide Epoxy	Ameron	71	Abrasive Blast	3.2	7
			Citric Acid	2.9	8
Polyamide Epoxy	Carboline	193	Abrasive Blast	4.0	Failed 66 Mo
			Citric Acid	3.8	Failed 66 Mo
Polyamide Epoxy	Devoe	202	Abrasive Blast	2.0	7
			Citric Acid	2.2	7
Polyamide Epoxy	Devoe	208	Abrasive Blast	2.1	6
			Citric Acid	1.8	Failed 32 Mo
Polyamide Epoxy	Devoe	230FD	Abrasive-Blast	6.1	10
			Citric Acid	5.4	10
Polyamide Epoxy	Farboil	4202	Abrasive Blast	2.0	Failed 13 Mo
			Citric Acid	1.8	5 @ 13 Mo
Polyamide Epoxy	Farboil	NAVY For. 150	Abrasive Blast	3.9	7
			Citric Acid	3.4	8
Polyamide Epoxy	Imperial	1219	Abrasive Blast	5.7	9
			Citric Acid	5.3	10
Polyamide Epoxy	International	EPA0061\ EBA744	Abrasive-Blast	3.9	Failed 32 Mo
			Citric Acid	3.7	7 @ 32 Mo
Polyamide Epoxy	Mobil	65T1\ 65F15B	Abrasive-Blast	4.0	Failed 32 Mo
			Citric Acid	3.6	Failed 32 Mo
Polyamide Epoxy	Napko	5616	Abrasive Blast	2.0	5
			Citric Acid	2.2	6
Polyamide Epoxy	Porter	4300 MCR43	Abrasive Blast	2.2	6
			Citric Acid	2.4	7
Polyamide Epoxy	Porter	24770	Abrasive Blast	2.5	7
			Citric Acid	2.8	8
Polyamine Epoxy	Ameron	2156	Abrasive Blast	4.9	9
			Citric Acid	5.4	9
Polyamine Epoxy	Byco	E-Prime 60	Abrasive Blast	6.8	9
			Citric Acid	5.8	9
Polyamine Epoxy	Carboline	187HFP	Abrasive Blast	7.0	6
			Citric Acid	7.6	7
Polyamine Epoxy	Mobil	71F84B\ 71T1	Abrasive Blast	2.6	Failed 32 Mo
			Citric Acid	2.7	Failed 32 Mo
Polyamine Epoxy	Mobil	264F25\ 264T24	Abrasive Blast	3.9	10
			Citric Acid	3.9	10
Polyamine Epoxy	Napko	5628	Abrasive Blast	3.5	10
			Citric Acid	3.5	10
Polyamine Epoxy	Porter	7650	Abrasive Blast	2.0	6 @ 7 Mo
			Citric Acid	1.8	7 @ 7 Mo
Epoxy Ester	Byco	360-1	Abrasive Blast	3.2	9
			Citric Acid	3.1	9
Epoxy Ester	Farboil	8229	Abrasive Blast	1.8	Failed 32 Mo
			Citric Acid	2.2	6 @ 32 Mo
Alkyd	Byco	400-2	Abrasive Blast	2.5	7
			Citric Acid	2.5	8
Alkyd	Farboil	1253	Abrasive Blast	3.3	7
			Citric Acid	3.0	8
Alkyd	Farboil	6031	Abrasive Blast	2.3	7
			Citric Acid	2.1	8

Table VI (cont'd.)

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
Alkyd	Imperial	62	Abrasive Blast	2.9	8
			Citric Acid	2.7	8
Alkyd	International	CPA476	Abrasive Blast	2.4	6
			Citric Acid	2.2	7
Alkyd	Mobil	53R1	Abrasive Blast	2.8	3
			Citric Acid	2.8	3
Alkyd	Napko	1313	Abrasive Blast	2.7	7
			Citric Acid	3.0	9
Alkyd	Porter	297	Abrasive Blast	2.5	7
			Citric Acid	2.6	7
Vinyl	Ameron	86	Abrasive Blast	1.6	Failed 4 Mo
			Citric Acid	1.0	Failed 4 Mo
Vinyl	Ameron	33	Abrasive Blast	2.4	Failed 7 Mo
			Citric Acid	2.0	Failed 7 Mo
Vinyl	Byco	600-2	Abrasive Blast	2.2	7
			Citric Acid	1.7	7
Vinyl	Carboline	8HB	Abrasive Blast	2.8	Failed 32 Mo
			Citric Acid	2.9	6 @ 32 Mo
Vinyl	Farboil	6600S	Abrasive Blast	3.2	6
			Citric Acid	3.1	5
Vinyl	International	VXL000	Abrasive Blast	3.3	10
			Citric Acid	3.0	10
Vinyl Wash Primer	Porter	VC17	Abrasive Blast	1.2	Failed 3 Mo
			Citric Acid	0.9	Failed 3 Mo
Chlorinated Rubber	Carboline	3631	Abrasive Blast	2.3	6
			Citric Acid	2.4	6
Chlorinated Rubber	Devoe	MD3500	Abrasive Blast	1.7	Failed 13 Mo
			Citric Acid	1.6	Failed 13 Mo
Chlorinated Rubber	Farboil	58ACG	Abrasive Blast	1.9	Failed 32 Mo
			Citric Acid	1.6	Failed 32 Mo
Chlorinated Rubber	Imperial	880	Abrasive Blast	4.8	7
			Citric Acid	5.0	6
Chlorinated Rubber	International	LPA300	Abrasive Blast	2.8	4
			Citric Acid	2.8	4
Chlorinated Rubber	Mobil	67F34	Abrasive Blast	3.9	9
			Citric Acid	4.2	9
Chlorinated Rubber	Napko	5202	Abrasive Blast	4.2	6
			Citric Acid	4.1	6
Ketamine Epoxy	Devoe	244HS	Abrasive Blast	3.7	8
			Citric Acid	3.3	6
Bituminous	Devoe	4314	Abrasive Blast	2.5	Failed 13 Mo
			Citric Acid	2.3	Failed 13 Mo
Bituminous	International	JAA021	Abrasive Blast	3.8	10
			Citric Acid	3.6	10
Phenolic-Vinyl	International	NFA081	Abrasive Blast	2.1	8
			Citric Acid	2.1	8
Water Borne (Emulsion)	Byco	500-1	Abrasive Blast	2.4	Failed 7 Mo
			Citric Acid	2.1	Failed 7 Mo
Water Borne (Emulsion)	Farboil	8285	Abrasive Blast	3.1	Failed 32 Mo
			Citric Acid	3.1	Failed 32 Mo

2.3 Touch-Up Surface Preparation Test

2.3.1 Test Panel Preparation

Twenty different primers representing twelve generic types were selected at random for the touch-up surface preparation test. The test panels were 6" X 18", A-36 steel panels which were first abrasive blasted to Steel Structure Painting Counci1 Surface Preparation Standard SSPC SP 10, "Near White Blast" and then primed. Each primer selected was applied to the top and bottom third of two each, steel panels. The center third was left bare. Following cure of each coating, a 3/4" weld was made through a portion of the coating and into the unpainted area. See Figures 2.9 for an example of a panel prior to exposure. The prepared panels were then placed on an exterior test rack at 45 South for ten weeks and allowed to rust. After the exposure period, the panels were removed from the rack and one panel from each set was touch-up cleaned using a citric acid spray technique, and one panel from each set was power tool cleaned in accordance with the procedure defined for erection joints in "Catalog of Existing Small Tools for Surface Preparation and Support Equipment for Blasters and Painters." During the citric acid operation it was noted that the citric acid reacted with the alkyl inorganic zinc types of primers (solvent based) and removed the majority of the zinc leaving the panel essentially bare. The water based self cure was removed to a lesser degree and the post cure inorganic zinc was not disturbed. It must also be pointed out that the citric process did not remove residual weld slag or heat damaged initial primer. No attempt was made to supplement the citric acid cleaning with mechanical cleaning prior to touch-up priming. The touched-up panels were preprimed and placed back on the exterior test fence at 45 South for 64 months.

2.3.2 Test Results of Touch-Up (Repair) Panels

Table VII contains a tabulation of the test results. The overall performance of the citric acid touch-up cleaned surfaces was inferior to the power tool touch-up cleaned surfaces. Figure 2.10 also shows a direct comparison of the performance of power tool cleaning and citric acid cleaning(citric acid panels are on the right in each panel set). The citric acid cleaned primer failure is due to weld damaged paint. In conclusion, citric acid cleaning for touch-up of damaged weld areas must be supplemented with a mechanical cleaning method to remove residual slag, weld splatter, and damaged paint.

Figure 2.9: Touch-Up Panel Prior to Initial Exposure

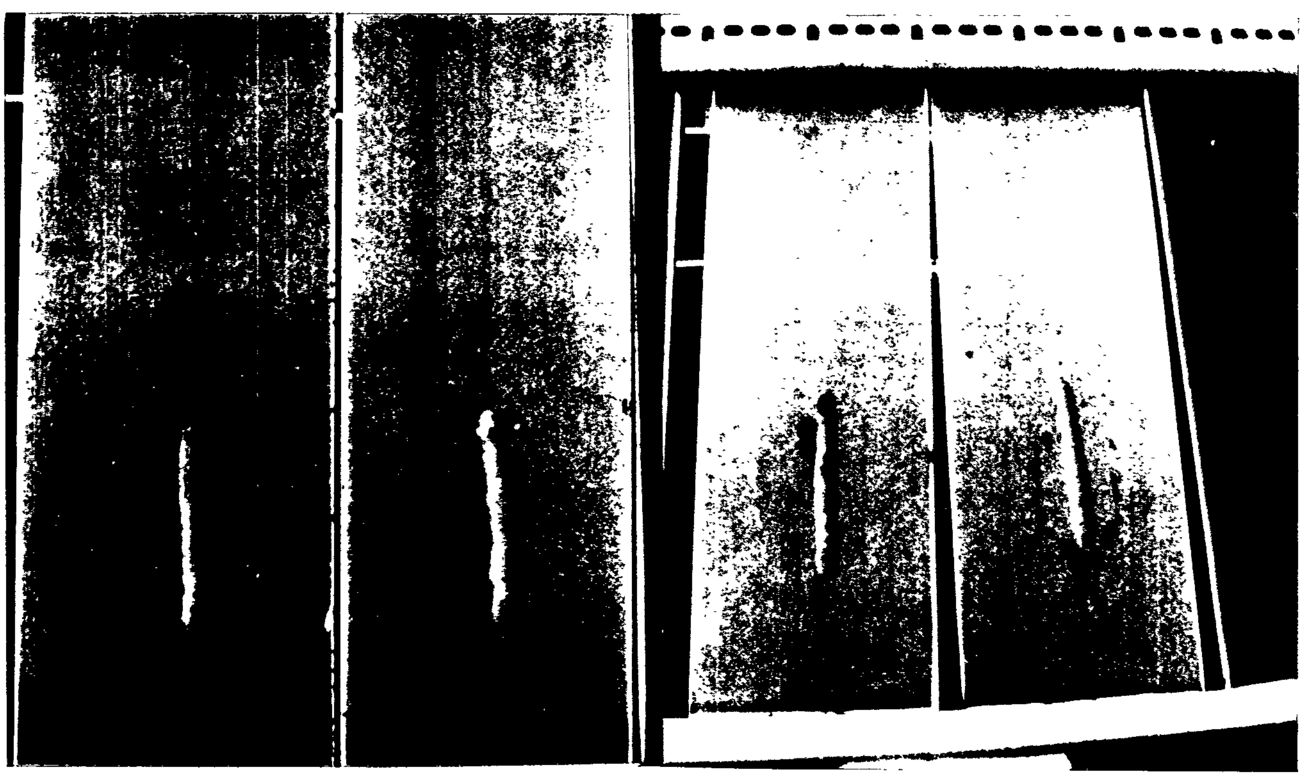


Figure 2.10: Touch-Up Panels After 64 Months Exposure

2.4 Comparison of Various Generic Types of Primers

In addition to the observations concerning the comparison between abrasive blast panels and citric acid cleaned panels, several other comparisons of generic types can be drawn. For example, the two component inorganic zincs outperformed all other primers exposed on the test fence. With the exception of one water based , self cured product which failed at three months, the remainder continue to provide excellent corrosion protection. It can also be noted that, of the systems tested, the two component inorganic zinc primers outperformed the organic zinc rich materials. Another interesting finding concerns the one component inorganic zinc primers applied over abrasive blast cleaned panels. Two failed at 18 months with two others having a rust grade rating of 4 and 6 respectively at 66 months. The alkyd primers are good performers, surpassing the polyamides epoxies, vinyls and chlorinated rubbers. The one component epoxy is the worst performer of those tested after 66 months; however, these materials are only designed for 6 to 9 months protection prior to topcoating. It should also be noted that one aluminum pigmented bituminous primer applied 3.8 roils dry has no rust.

Table VII: Touch-up Surface Preparation Performance of Various Primers Applied to Either Power Tool Cleaned or Citric Acid Cleaned Prepared Panels After 64 Months

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
Post Cure Inorganic Zinc	Ameron	D-3	Power Tool	5.6	9
			Citric Acid	5.3	10
Water Based, Self Cure Inorganic Zinc	Ameron	D4	Power Tool	2.5	10
			Citric Acid	2.1	10
Alkyd Inorganic Zinc	Carboline	CZ11	Power Tool	4.8	10
			Citric Acid	4.3	10
Alkyd Inorganic Zinc	Mobil	13F12	Power Tool	3.3	10
			Citric Acid	2.7	10
Alkyd Inorganic Zinc	Sigma	711G	Power Tool	4.0	9
			Citric Acid	3.4	9
Alkyd Inorganic Zinc	Mobil	28DH50	Power Tool	2.3	9
			Citric Acid	1.8	9
One Component Inorganic Zinc	Devoe	306	Power Tool	5.6	9
			Citric Acid	4.6	10
One Component Inorganic Zinc	Mobil	13G10	Power Tool	2.2	Note 1
			Citric Acid	1.6	Note 2
Modified Inorganic Zinc	Porter	352	Power Tool	3.0	10
			Citric Acid	2.5	10
One Component Epoxy Zinc Rich	Napko	1355	Power Tool	5.6	9
			Citric Acid	4.5	9
Polyamide Epoxy	Carboline	193HB	Power Tool	5.6	10
			Citric Acid	4.3	10
Polyamide Epoxy	Devoe	208	Power Tool	2.4	Failed 30 Mo
			Citric Acid	2.0	Failed 30 Mo
Polyamide Epoxy	Napko	5616	Power Tool	2.4	9
			Citric Acid	7.0	8
Alkyd	Imperial	62	Power Tool	4.7	8
			Citric Acid	5.4	8
One Component Epoxy	INT	NEA200	Power Tool	3.4	10
			Citric Acid	3.3	9
Ketamine Epoxy	INT	TTA424	Power Tool	5.9	Note 3
			Citric Acid	5.8	8

Note 1: Failed in Repair Area
Note 2: Failed in Top Half of Panel, Repair Area Rust Grade 10
Note 3: Failed in Weld Area

2.5 Inorganic Zinc Primers Applied Over Four Types of Abrasives

To investigate the possible impact of abrasive selection on paint performance, a limited test program was initiated to test the performance of inorganic zinc primers applied over four different abrasives. Six alkyl inorganic zinc primers were applied to two sets of panels prepared using a coal slag, a mineral sand, a silica sand, and GL-40 steel grit abrasives. Film thicknesses within a supplier set were controlled by applying the materials to all four panels simultaneously. Film thicknesses between supplier sets ranged from 2.3 to 7.0 roils. All panels were then exposed on an exterior test rack. After 60 days, one set was removed and placed in a salt fog cabinet for 6000 hours. The salt fog test was performed in accordance with ASTM B117. After 6000 hours, all panels had a rust grade of 10. In addition, all panels which were left exposed on the test fence for 66 months, within a supplier set, had the same degree of rust. Rating between. sets varied from 9 to 10 rust grades.

References

1. Peart, John, "Catalog of Existing Small Tools for Surface Preparation and Support Equipment for Blasters and Painters", The National Shipbuilding Research Program, May, 1977.

2. Fultz, Benjamin S. "Cleaning of Steel Assemblies and Shipboard Touch-Up Using'Citric Acid (Phase I), The National Shipbuilding Research Program", May, 1980.

3. Fultz, Benjamin S. , "Marine Coating Performance for Different Ship Areas", The National Shipbuilding Research Program, July 1979.